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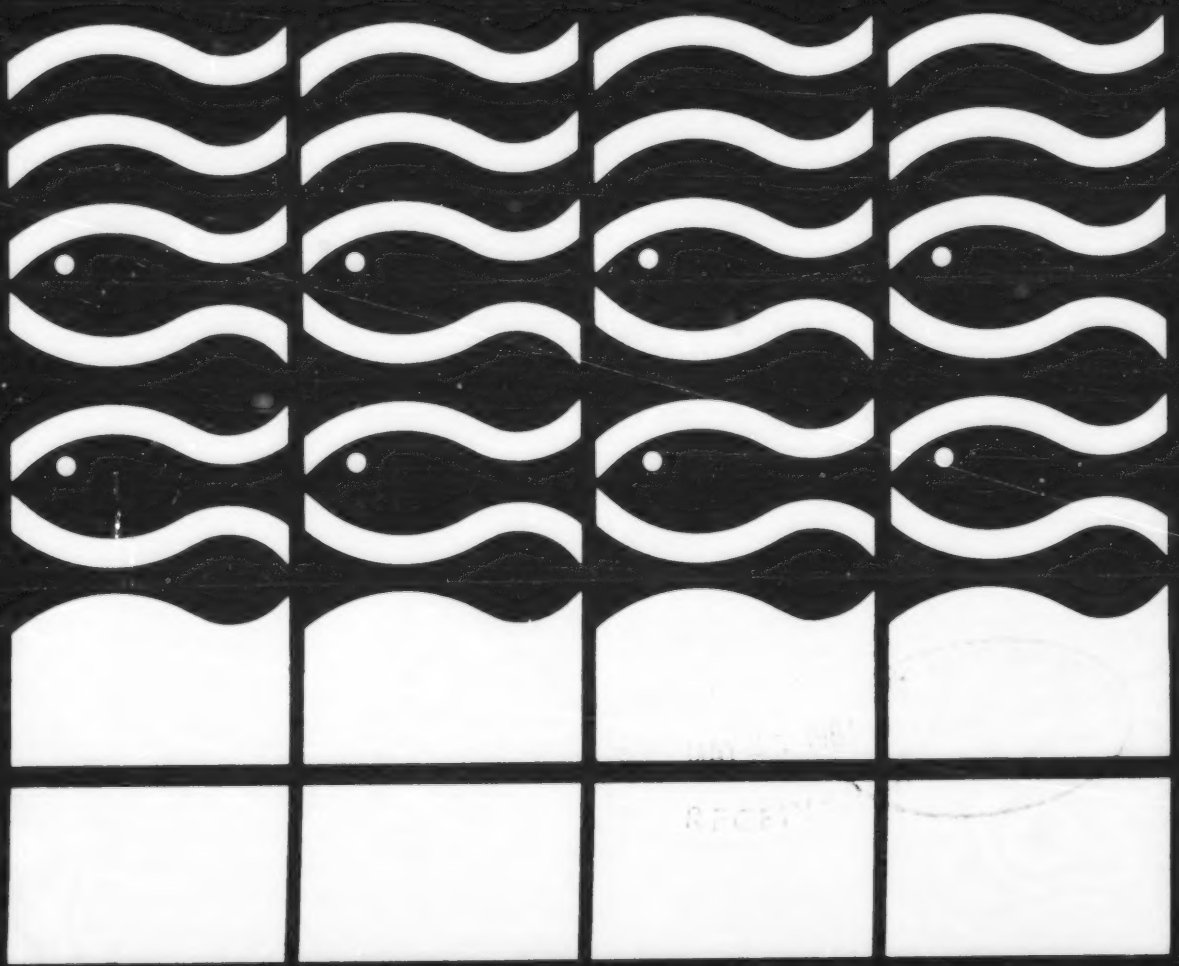
Report



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AN ASSESSMENT OF THE FUEL EFFICIENCY OF VESSEL/GEAR COMBINATIONS IN USE IN THE NEWFOUNDLAND FISHERY

Prepared for
FISHING INDUSTRY ADVISORY BOARD
St. John's Newfoundland

by

NORDCO LIMITED
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MARCH, 1981

Opinions expressed and conclusions reached by the authors are not necessarily endorsed by the sponsors of this study.

FOREWORD

An important part of the cost of fishing is represented by the cost of fuel. It is commonly recognized that most passive fishing methods are more economical, in terms of fuel consumption per unit of catch, than most active fishing methods. It is also recognized that larger vessels generally require more fuel per hour of operation, than smaller vessels utilizing similar fishing methods.

Simply deploying the smallest possible vessels utilizing the most economical gear, might produce marginally acceptable results in some fisheries. But for an industrial fishery which is the main source of income in many areas of Newfoundland, this would not be a viable operational strategy. In response to rapidly escalating operational costs, it will be necessary to develop more efficient vessels and more efficient gears, and to use them in the most effective combinations.

To this end, the Fishing Industry Advisory Board commissioned NORDCO Ltd. of St. John's, Nfld. to undertake a study into the relative fuel efficiency of various types of fishing operations as practiced in Newfoundland.

This report is intended to provide some very basic analysis of vessel and gear performance in terms of fuel efficiency for Newfoundland conditions. It is hoped that this will form the basis for further economic and technical research to improve the performance of the fishery.

FRANK DOPPLINGER,
Chairman.

April 1st, 1981

Executive Summary

This report presents the results of a study analysing the relative fuel efficiency of different sectors of the Newfoundland fish harvesting fleet. In order to make this assessment, data for the total fishery in 1978 was used. There are considerable problems in attempting to estimate fuel used by sectors of the fleet using particular gear types. A scheme using averages based simply on the size of vessels was used for a first approximation. Modifications to the interpretations were then made based, in part, on a survey of activities of a sample of vessels.

The approach taken in this report corroborates preliminary studies made for fisheries in other parts of the world. The results indicate that nearshore vessels are considerably more fuel efficient than midshore or offshore vessels. Static fishing gears require little mechanical power for their operation but do result in high yields, and this clearly translates into a relatively low use of fuel for each fish landed.

There is a more than tenfold difference in fuel efficiency between an inshore vessel operating a cod trap and an offshore stern trawler. Differences between some intermediate gear combinations have not been so clearly demonstrated in this study, for instance the fuel efficiency of larger vessels using longlines and gillnets seems to be similar to small nearshore vessels using otter trawls.

The results of this analysis do not lead to any specific recommendation with regard to optimum matching of power and vessel size to particular harvesting technologies but simple interpretation would suggest the use of the smallest engines possible. On the basis of fuel efficiency, the optimum harvesting strategy for the Newfoundland fishery would accentuate the inshore fishery.

1.0 INTRODUCTION

The social, economic and cultural importance of the fishery to Newfoundland is well-known. Historically, it has proved capable of sustaining much of the labour force of the Province. With the declaration of the 200 mile economic zone by the Government of Canada in 1977, the potential for the economic exploitation of the marine resources were greatly increased. Technological innovations may enable Newfoundland to harvest these resources more fully than in the past, but the economic viability of such efforts is likely to be seriously challenged, in the future, by the high fuel costs involved in fishing activities.

The current Newfoundland fishing fleet shows great diversity in vessel characteristics as well as in harvesting technology. It is comprised of over 15,500 inshore boats of lengths less than 35 ft.; over 1,000 nearshore vessels of 35 ft. to <65 ft.; 18 midshore vessels of 65 ft. to <100 ft.; and 89 offshore vessels of lengths over 100 ft.[1]

Except in the case of offshore wet-fish stern trawlers, most of the fishing fleets engage in multi-species activities using a variety of gear combinations. During the year 1978, the Newfoundland fleet, of vessels longer than 35 feet, made over 39,000 trips to the fishing grounds and landed an all-species catch of approximately 300,000 metric tons valued at $54 million. The projections for the year 1985 are 994,000 metric tons to be harvested by the entire fleet and valued at $212 million (1980 dollars). Harvesting of this three fold projected landings will require greater fishing activities resulting in high demands for fuel.

The fuel consumption of the fishing fleet is dependent upon the main engine power of each vessel and its usage patterns. In the Newfoundland setting, the main engine power within each size of

[1] Department of Fisheries and Oceans, Economics and Statistics Branch, St. John's, Newfoundland.

fishing boat is highly diverse as shown in Table 1. This large range is suggestive that some vessels may not be fuel efficient.

Fuel consumption is an important running expense in fishing operations. It is hoped that an analysis of fuel usage patterns in different fisheries will provide a basis for the choice of the more appropriate harvesting technology or assist in developing plans for harvesting stategies and fisheries management.

It is commonly held view that smaller vessels employing fixed gears are highly fuel efficient. To examine this view, this study undertakes an objective assessment of the fuel consumption pattern of the Newfoundland fishing fleet and compares these results with Scandinavian assessments.

This study used data from the 1978 Landings and Efforts file of the Department of Fisheries and Oceans, St. John's, Newfoundland for Newfoundland vessels >35 ft. This data was supplemented by a limited field survey involving 40 vessels of length class 25 ft. - 65 ft. The goal was to assess the relative fuel efficiency of vessel-gear combinations involving all phases of fishing operation by comparing the fuel consumed with the corresponding landings in terms of weight, value and energy content. For this purpose, three indices of fuel efficienty were used:

1. Specific Usage: $\frac{\text{Fuel consumed (lbs.)}}{\text{Fish landed (lbs.)}}$

2. Specific Cost: $\frac{\text{Cost of fuel consumed (\$)}}{\text{Value of fish landed (\$)}}$

3. Energy Ratio: $\frac{\text{Fossil fuel energy (Giga Joules)}}{\text{Catch Energy (Giga Joules)}}$

The first two indices reflect the utilization of fuel energy for a unit of catch taken in terms of quantity of fish landed or the value of this catch. The third index of energy ratio provides a measures of fuel energy used per unit of energy obtained in the catch.

Table 1: Size and Power Breakdown of the Newfoundland Fishing Fleet in 1978

Length Groups (ft.)	No. of Vessels in Each Length Group	No. of Vessels in Designated Length Groups	Average Power (b.h.p.) in each Length Group	Average Power (b.h.p.) in Designated Length Groups	Ratio: column(4) / column(5)	No. of Vessels Using Principal Gears	
						Fixed	Towed
5< 15	557		12.0		0.63	All Vessels	-
15< 25	12357		18.3		0.96	All Vessels	-
25< 35	2795	15709	22.7	19	1.19	All Vessels	-
35< 45	590		90.6		0.72		
45< 55	370		146.8		1.18	1548	138
55< 65	89	1049	255.9	125	2.05		
65< 76	11		363.6		0.90		
75< 85	4		412.0		1.02	12	7
85< 95	3	18	560.0	405	1.38		
95<105	4		320.0		0.26		
105<115	2		257.5		0.22		
115<125	13		656.2		0.53		
125<135	10		721.5		0.59		
135<145	10		1101.2		0.90	28	126
145<155	27		1611.9		1.31		
155<165	7		1500.0		1.22		
165<175	15		1459.3		1.19		
205<215	1	89	2500.0	1230	2.03		

Specific usage provides a measure of fuel efficiency which is outside the influence of economic factors and can be compared at any point in time. Thus this index is useful in energy conservation measures incorporated in long range fisheries planning. The index of Specific Cost varies with time. It is an indication of the economics of fish harvesting and is effected by relative prices of fuel and fish. Energy ratio defines the fossil fuel energy consumed per unit of energy obtained in the catch. This information may be found useful by scientists interested in a more global energetics approach.

Some extension of the results obtained in assessing vessels larger than 25 feet has been attempted for vessels smaller than this size. The relationship between fish consumed in specific fisheries and the number of crew involved was examined in order to see whether fuel consumption could be changed by development of harvesting sectors employing more manual labour.

2.0 LANDINGS FROM NEWFOUNDLAND HARVESTING EFFORT

A basic input into this study was an assessment of the catch realized by the Newfoundland fishing fleets. These fleets involve many vessel-gear combinations which are engaged in the catching of more than one species during the year. Total annual landings for 1978 by species by gear type for each vessel class were obtained as a primary data source from the Economics and Statistics Branch of the Department of Fisheries and Oceans, St. John's, Newfoundland. A consolidated version of this data, shown in Table 2, highlights the variety of gear types used by each vessel size group to land each species.

To obtain specific information on landings and effort, a field survey of a few vessels was conducted during August, 1980. The information on landings obtained through this effort was in the broad categories of ground-, pelagic- and shell-fishery as is discussed later in this report.

2.1 Value of Landings

Concurrent with the record of landings maintained by the Department of Fisheries and Oceans, there is a record maintained of the landed values of catches by species. The total aggregate value of landings for all species landed by each vessel - gear combination was used in this study. Data from the field survey provided information on the total landed value of catches of groundfish, pelagic fish and squid for a few selected vessels in the length category of 25-65 ft.

2.2 Energy Content of Landings

The energy content of fish is contained in edible portions and offal and varies for each species. Table 3 gives the energy values of species of fish generally caught in Newfoundland waters. This information was used to convert landings data to the respective energy values for each species. Total energy for landings was obtained by a summation, for all species landed by each vessel-gear combination, for the data obtained from the Department of Fisheries and Oceans.

TABLE 2: Total Annual Landings, Value and Effort Statistics Used in These Analyses

Vessel Size		Traps	Handlines	Gillnets	Longlines	Shrimp Trawls	Side Trawls	Stern Trawls	Midwater Trawls	Scottish Seines	Scallop Dragger	Pair Seine
<35 feet												
	Landings (tonnes)	40845	22275	43502	19742							
	Value ($000)	19050	6018	10659	6122							
35-65 feet												
	Landings (tonnes)	15620	491	38902	9497	1509	6454	1626		2094	37	282
	Value ($000)	5616	142	10214	3002	1976	1876	454		607	27	71
	Effort	5880(t)	720(t)	19917(t)	5632(t)	25942(h)	18436(h)	3156(h)		9634(h)	198(h)	424(h)
65-100 feet												
	Landings (tonnes)			1323		27	407			197		
	Value ($000)			305		15	105			44		
	Effort			242(d)		92(h)	702(h)			347(h)		
100+ feet												
	Landings (tonnes)			1050	423	1538	26601	128293	8092			
	Value ($000)			244	115	950	4269	24661	1081			
	Effort			181(d)	107(d)	2813(h)	51993(h)	167071(h)	5031(h)			

Effort: t=trips
d=days
h=hours

TABLE 3

Energy Value Table for Different Fish Species

Species	Energy[1] (Cal/Kg)	Energy[2] (Cal/Kg)	Energy Figures used in this study (Cal/Kg)
Capelin	940	-	940
Catfish	-	842 (± 30)	850
Clam	-	890	890
Cod	850	860 (± 56)	850
Crab (Queen)	920	810	870
Crab (Unspecified)	810	815	810
Cusk	890	-	890
Dogfish	-	1000	1000
Eel	1780	1105	1100
Flounder	730	843-877	770
Greenland Halibut	1870	-	1870
Greysole	730	825	770
Haddock	820	790	810
Halibut	1400	1260	1260
Herring	1730	1020	1020
Lobster	810	950	870
Lumpfish	-	-	850 (Estimated)
Mackerel	1680	1034 (± 173)	1100
Plaice	730	825	770
Pollock	770	-	770
Redfish	780	-	780
Salmon	1400	-	1200
Scallops	890	-	890
Shrimp	810	883 (± 97)	860
Skate	-	800	800
Smelt	940	-	940
Squid	-	890	890
Swordfish	-	1000	1000
Trout	1400	-	1360
White Hake	860	860	860
Yellowtail	730	825	770

Footnotes for TABLE 3

Fat	9020	9000	9000
Protein	4770	4000	4000

[1]Dyer, W.J. et. al Retail Frozen Fishery Products - Proximate and Mineral Composition of the Edible Portion, Journal of the Institute of Canadian Food Science and Technology. Vol. 10 #3, July 1979 pp. 185-187.

[2]Sdwell, V.D. et. al. Composition of the Edible Portion of Raw (Fresh or Frozen) Crustaceans, Finfish and Mollusks. Protein, Fat, Moisture, Ash, Carbohydrates, Energy Value, and Cholesterol Marine Fisheries Review Vol. 36, No. 3 March 1974, pp. 25-32.

3.0 FUEL CONSUMPTION

Fuel consumption in its most simple form is a function of the main engine power of the vessel and its usage. The data on engine horsepower for vessel size groups (Table 1) does not necessarily reflect any specific requirement for use in any given fishery. In this study, analysis is based on the average brake horsepower (b.h.p.) for each of the length groups. The implications of this assumption will be discussed later.

Different fishing activities require different power usage. For dynamic gears, the engine usage is almost continuous during each trip. However, this study has only used the data of recorded duration of actual use of these fishing gears. This became necessary because the minimum unit of recording of trip duration is one day. This large basic unit leads to errors in estimation of the duration of engine usage for vessels having short trips. For instance, the inshore vessels using dynamic gears often have trips lasting between 1 and 3 days making the potential error in estimating duration of engine use from $\pm$100 to $\pm$30% respectively. Use of recorded data on the number of hours of fishing activities allows a more accurate estimate of fuel used in fishing but of course does not include estimates in fuel used in travelling to and from fishing grounds.

It has been assumed that these vessels used full power during the fishing operations and, for vessels over 65 ft. LOA, additional fuel consumed by auxiliary engines was estimated as 33% of fuel used by the main engine. Both of these estimates can be considered near the maximum likely to be used. During fishing, even with towed gear, it is not likely that more than 75 to 90% of the power is required for routine operation. In the absence of specific data on either of these points these assumptions have been used for all calculations.

In the case of static gears, the gears are left in-situ so that time recorded for fishing activities is not always related to the duration of use of the engine. For these situations, the duration of engine use was estimated from experience and discussions relative to

the Newfoundland fishery and confirmed by data from the survey of fishermen. The estimated hours of engine use per trip for different gears are shown in Table 4. For the 65 - 100 ft. gillnetters the equivalent of the smaller gillnetters was used; i.e.; 8.5 hours of full engine power per day fished and an additional 33% of main engine power was added to account for fuel used by auxiliary engines. In all these cases, the weight of fuel consumed during fishing trips was estimated by a conversion factor of 0.39 lb/b.h.p./hr.[1]

From the survey data, fuel consumption corresponding to landings in the broad categories of groundfish, pelagic and squid were calculated by pro-rating the annual fuel cost between these fisheries based on the length of their respective fishing seasons. For instance a vessel using $1,850.00 worth of fuel (available at 71¢ per gallon to that vessel) for a season in which effort was split 68% on groundfish, 17% on pelagics and 16% on squid would be estimated to have used $1,258.00 for groundfish (1770 gallons), $315.00 for pelagics (443 gallons), and $296.00 for squid (417 gallons). Fishermen did not provide data which allowed a more realistic breakdown. There seems little doubt that prorating on the basis of duration of season underestimates fuel consumption for the period of use of towed gears and overestimates fuel use in the period when passive gears are used. In practice few vessels exhibited this variation in gear use so this simple assumption was used in order to make estimates independent of those based on DFO data.

The average cost of diesel fuel for Newfoundland fishermen in 1978 was taken to be 0.66¢/gallon.[2]

The energy content of one pound of diesel fuel was considered to be equivalent of 4,662 Cal.[3]

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[1] Tips for Fishermen, #1, "Slow Down Save Fuel", vessels and Engineering Division, Industrial Development Branch, Fisheries and Marine Service, Environment Canada, Ottawa, Ontario, K1A 0H3.

[2] From data search (DFO).

[3] Theordore Bammerster (Ed.) Standard Handbook of Mechanical Engineering, McGraw Hill Book Company, New York.

Table 4: Estimated Fuel Consumption Hours for Vessels Using Fixed Gears[1]: Vessel Length Class 35-<65 ft. LOA

Gear Type	Activity	Estimated Main Engine Hours Per Trip	Equivalent Full Power Hours(4)	Remarks
Traps (all types)	Steaming in and out(2)	3.5	5.0	(1) No auxiliary engine usage considered for vessels in this length class
	Other fishing activities(3)	6.0		
Gillnets	Steaming in and out	6.0	8.5	(2) Steaming time, generally varies from 2-5 hours for each fishing trip.
	Other fishing activities(3)	10.0		
Longlines and Gillnets	Steaming in and out	3.5	7.5	(3) Refers to net hauling time and other miscellaneous activities requiring power. (25% of main engine power is considered for these activities.)
	Other fishing activities (3)	12.0		
Handlines	Steaming in and out	2.0	2.1	(4) Estimated as full power for travelling combined with 25% of full power during fishing operations.
	Other fishing activities	0.5		

4.0 RESULTS AND DISCUSSIONS

In order to assess the data from our sources in an integrated manner, the results are presented for all vessel-gear combinations for each data source. The results are developed individually for the three indices of Specific Usage, Specific Cost and Energy Ratio.

4.1 Specific Usage

The results of analysis of Specific Usage are presented in Tables 5 and 6. The analysis presented in Table 5 indicates that for near shore vessels, use of static gears results in low estimates of Specific Usage. Midshore vessels undertook fewer trips and analysis of the available data suggests a similar difference in relative fuel efficiency between static and dynamic gear usage. Use of static gears by offshore vessels was also estimated to be less fuel efficient than dynamic gears. These results were based on use of static gears by large vessels during relatively few fishing trips and may not adequately evaluate the fuel efficiently of the use of static gears by larger vessels since accurate estimates of engine use patterns were not available. For a meaningful assessment of relative fuel efficiency of this harvesting technology, more data would be required.

The fleet sector which shows the greatest diversity of gear use was in the 35-65 ft. range of vessels. Trap fishing and use of handlines is observed to be the most efficient of the fixed gears. The gillnet and longline fishery differ in size in different parts of the province but estimates of specific usage calculated on a province wide basis show little difference in fuel efficiency.

Comparison of the different fixed gear technologies across the vessel classes is of doubtful validity since such a comparison could be very sensitive to the initial assumption on engine use made in this study. However, this analysis suggests that the trap fishery and use of handlines by the inshore vessels may be the most efficient use of fixed gears.

Table 5: Specific Usage by Vessel/Gear Combinations (fuel/landings)

Vessel	Gear Type	Effort	Total Annual Fuel Consumed Fishing (tonnes)	All Species Catch (tonnes)	Specific Usage	Rank
35-65ft. (Near shore vessels) 125bhp	Fixed					
	Traps (all types)	5880(t)	194	15620	0.01	1
	Gillnets	19917(t)	1103	38902	0.03	3
	Longlines/ Gillnets	5632(t)	373	9497	0.04	4
	Handlines	720(t)	8	491	0.02	2
	Encircling					
	Scot.Seine	9634	212	2094	0.10	6
	Pair Seine	424x2(h)	18	282	0.06	5
	Towed					
	Shrimp trawl	25942(h)	583	3509	0.17	9
	Side trawl	18436(h)	415	6454	0.06	5
	Stern trawl	3146(h)	71	1626	0.04	4
	Scallop dragger	198(h)	4	37	0.12	7
65-100ft. (Midshore vessels) 405bhp main. 134bhp aux.	Fixed					
	Gillnets	242(d)	58	1323	0.04	4
	Encircling					
	Scot. Seine	347(h)	34	197	0.17	9
	Towed					
	Shrimp trawl	92(h)	9	27	0.33	11
	Side trawl	702(h)	68	407	0.17	9
100ft. (offshore vessels) 1230 bhp main 406 bhp aux.	Fixed					
	Gillnets	181(d)	133	1050	0.13	8
	Longlines/ Gillnets	85(d)	74	422	0.18	10
	Towed					
	Shrimp trawl	2813(h)	828	1538	0.54	13
	Side Trawl	51993(h)	15310	26601	0.58	14
	Stern trawl	167071(h)	49296	128293	0.38	12
	Midwater trawl	5031(h)	1482	8092	0.18	10

Effort: t=trips
d=days
h=hours

able 6: Summary of Results: Survey Data

essel ength Class	GROUND FISHING Specific Usage	GROUND FISHING Specific Cost	PELAGIC FISHERY Specific Usage	PELAGIC FISHERY Specific Cost	SQUID FISHERY Specific Usage	SQUID FISHERY Specific Cost
25- 35ft.						
Mean	0.08	0.06	0.10	0.09	0.12	0.10
S.D.	0.05	0.02	0.11	0.05	0.10	0.09
n	(10)	(10)	(7)	(7)	(7)	(7)
35- 45ft.						
Mean	0.09	0.07	0.06	0.07	0.01	0.13
S.D.	0.07	0.06	0.03	0.03	0.18	0.19
n	(8)	(8)	(3)	(3)	(3)	(3)
45- 55ft.						
Mean	0.11	0.08	0.03	0.04	0.08	0.01
S.D.	0.07	0.04	0.02	0.03	0.07	0.08
n	(10)	(10)	(8)	(8)	(6)	(6)
55- 65ft.						
Mean	0.15	0.11	0.06	0.05	0.21	0.10
S.D.	0.06	0.05	0.05	0.02		
n	(6)	(6)	(4)	(4)	(1)	(1)

.D. = Standard Deviation

No such limitations arise in comparing the results of analysis of dynamic gears where data on engine use patterns is available. In the case of otter trawling, by stern or side trawlers, smaller vessels give better estimates of Specific Usage. Among the larger vessels (greater than 100 ft.) the midwater and stern trawling are most efficient but their specific usage is approximately 10 fold higher than the less than 65 foot vessels (0.38 versus 0.04). In the calculation of efficiency indices in this analysis an attempt has been made to examine the fuel efficiency with reference only to the fuel used in setting, hauling or towing fishing gears. A further consideration should be the amount of fuel used by vessels travelling to and from their grounds. In general it may be assumed that the smaller vessels do not travel so far. The larger vessels do travel further to their offshore grounds in search of fish. They also remain longer on the grounds in an attempt to maximize the efficient use of the fuel used in steaming, e.g. 65-100 foot gillnetters fish for approximately 3 days per trip and offshore trawlers for 9 days per trip (see Table 10).

Offshore vessels often travel for one day or more for each trip of 9 days fishing but our analysis has not included any estimates of fuel used during this time. This means that estimates of Specific Usage are probably underestimated by more than 10% for these vessels. Inshore trawlers which probably do not travel so far to their fishing grounds so that estimates of fuel use are probably more accurate.

The use of an average power for vessel groups is a convenience to estimate the fuel use indices but some discussion can be given to this factor. Vessels of less than 35 feet have an average power of about 20 b.h.p. and engage totally in fixed gear fisheries. The average power (125 b.h.p.) used to calculate a fuel used by 35-65 foot vessels is no doubt an over estimate for most the vessels of this size range engaged in fishing using the same type of fixed gears as smaller vessels (Table 1). For similar vessels using towed gears a high power output is required and it might be assumed that the vessels engaged in these fisheries were the higher powered vessels. If this was the case

the estimate of specific usage for a 64 foot vessel used in otter trawling might have been underestimated by a factor of 2.05 (from Table 1) so that the Specific Usage of an inshore side trawler might be closer to 0.13 than the 0.06 estimated in Table 5.

Analysis of the fuel efficiency of the Newfoundland fishery is particularly difficult since the landings by the vessels less than 35 feet in length account for most of the inshore fishery but no data is available for their fishing effort from which fuel use estimates could be made. As an example - 74% of the Northern Cod landed by inshore vessels is taken by the small inshore vessels but we do not know how many of the small vessels are actually used or how many trips they make. If all of the small vessels participated fully their annual catch per vessel would be about 10 fold less than 35-65 foot vessels according to data in Tables 1 and 2. According to Table 1 the average power of the small inshore vessels is 19 b.h.p as opposed to 125 b.h.p. for 35-65 foot vessels (i.e. 1/7 of the power and presumably 1/7 of the fuel consumption). If the average vessel landed 1/10 of the quantity using 1/7 of the fuel the Specific Usage index might be approximately 10/7 (1.4 times) the index of a comparable nearshore vessel. However if we assumed that the index was the same for all vessels below 65 feet in a given fishery we would have to assume that not all vessels smaller than 35 feet were involved fully in the fishery and that landings by the active vessels were 1.4 times higher than the average. For this case to be true effort must be equivalent only to about 70% of the licensed vessels working full time. Since there are many fishermen in this class who do not fish a full season this argument suggests that the inshore vessels are likely to be as efficient as nearshore vessels. Further study of the efficiency of this important fleet sector is urgently needed.

For the midshore vessels (65-100 foot) it seems probable that the more highly powered vessels are those engaged in towed gear fisheries but the range of power in this grouping is not great (0.9 - 1.38 times the average). Perhaps the Specific Usage index for 65-100 ft. side trawlers may range from 0.17 up to 0.23 and for the gillnets, if they

are used by the least powerful vessels would be slightly lower than the 0.04 estimated (Table 5).

The range of power outputs from the offshore vessels (greater than 100 feet) is very large and may be a combination of older underpowered vessels using towed gears and low powered vessels using fixed gears. It is possible that the high powered vessels are those engaged in the offshore otter trawling; fuel consumption of these vessels would likely be 1.2 to 1.3 times the rates estimated by the mean so that specific usage might be expected to approximate 0.69 for a large side trawler. The gillnetters, longliners and side trawlers are less powerful so that the specific usage indices for these vessels are no doubt overestimated.

Despite these uncertainties the basic ranking of fuel efficiency estimated using specific usage would not change much. The differences between fixed and dynamic gears shown in Table 5 are probably underestimated which makes it difficult to assess whether for instance an inshore dragger is really more fuel efficient than an offshore gillnetter longliner.

When specific operations of individual vessels in the 25 - 65 foot range were surveyed insufficient detail could be gathered to look at particular gear types and even an analysis of variance between the vessel sizes and between the groundfish, pelagic and squid fisheries showed no significant differences (Table 6). This was due in part at least to the large range of rated power output from vessels in this size range (Appendix I). In twelve vessels which used no dynamic gears in the 1979 fishery there was a range of 8-115 b.h.p. and the 18 vessels which did use dynamic gears in some parts of the fishery ranged in power output from 85 to 365 b.h.p. The results of this survey do confirm that interpretation of the analysis based on the data for the entire Newfoundland fishery should be treated with caution since it will have tended to have hidden both the grossly inefficient and the highly efficient vessels. The high variability demonstrated by vessels examined in this brief survey indicates

however that there is potential within the Newfoundland fleet for both improvement in some areas of gear or vessel choice, and also for identification of some vessels which are close to the optimum.

Table 7 shows some estimates of the power appropriate to particular fisheries based simply on the range of power that is suited to technical operation of the specific gear types. By substituting these estimates in the calculations used to produce Table 5 the specific usages that would result from use of these powers in the Newfoundland fishery are seen. It is clear that if specialization of vessels and optimization of the matching of power to the fishery occurred than there would be potential to see an increase differential of specific usage index between fixed gears used by small vessels and dynamic gears used by large vessels.

Studies in Norway (Endal - Appendix II) indicated gillneters, longliners and Scottish seines to be greater than three times as fuel efficient as large stern trawlers. However, even the passive gears were not as fuel efficient as purse seiners which, when they find schools of fish, catch high volumes using very little power. By looking at the energy quotient it was evident that the purse seiners were the most efficient and shrimp trawlers and large wetfish trawlers the worst. In the study of the Newfoundland fleet the same tendencies have been confirmed and it is indicated that the inshore trap fishery may be even more fuel efficient than the gillnets and longliners which showed up well in the Norwegian study. Purse seines could not be adequately assessed with the data base used and are in any case used only for pelagic species in Newfoundland.

A study by Frehling[1] indicated that the Dutch coastal and large vessel offshore fleets were suffering economic strains due to the increased cost of fuel. It is evident from the results of the Newfoundland study that it is the trawlers of greater than 65 feet

[1]Discussed in Agra Europe 81 1980; Dutch inshore fleet most affected by fuel price increase.

TABLE 7: Definition and Projected Performance of Some "Optimised" Vessel Configurations

Vessel Length	Ideal Length	Gear Type	Ideal b.h.p.	Specific Usage From Table 5	Specific Usage for "Optimised" Vessel	Change
25-≤65	30	Trap	20	0.01	< 0.01	gain
		Gillnets	50	0.03	0.01	gain
		Longlines	50	0.04	0.02	gain
	65	Stern Trawling	400	0.04	0.14	loss
		Shrimp Trawling	300	0.17	0.40	loss
65-≤100	85	Trawling	700	0.17	0.29	loss
		Scottish Seine	500	0.17	0.21	loss
≥100	120	Bottom Trawling	1200	0.38	0.37	no change
		Midwater Trawling	1400	0.18	0.21	loss

which are most liable to such pressures. The smaller vessels, particularly with passive gears use very little fuel to catch their fish. In this study we have not been able to pinpoint whether the true inshore vessels of less than 35 feet are in fact more efficient than those of 35 to 65 feet. If, as seems likely, the number of days fishing in a season for inshore vessels is less than for the nearshore fleet it is probable that the trend of "smaller is better" would continue below 35 feet.

None of this discussion has touched upon the economic considerations of fuel cost and price of the catch. The specific cost index allows the merits of a high fuel use to catch a relatively low quantity of high value species, and vice versa, to be considered. For instance, in Table 8 shrimp trawling by offshore trawlers appears to give a better use of fuel on a cost basis than does otter trawling for groundfish, even though the yeild in weight (Table 2) was low. The same is true for 35 - 65 foot scallop draggers and the performance of small shrimp draggers is much better when assessed on the basis of this index relative to the groundfishery.

The specific cost for all traps combined is the lowest calculated for all gear types. It can be estimated that this is an underestimate for catches of cod, herring and capelin since the price for these species is lower than the price for crab (1978 prices; 26, 18, 10 and 51c per kg respectively) and total trap landings for all species was 15,521 tonnes of which 7479 was crab. Even allowing for this twofold underestimate for specific cost of trapping finfish, the trap used by 11-20 m vessels is the most cost effective gear.

A third index was calculated to examine the efficiency of use of fossil fuel energy relative to the harvesting of energy from natural production (Table 9). Any ratio greater than 1.0 indicates that the energy in fossil fuel expended is not being returned in energy utilizable in food. It can be seen that most of the nearshore vessels do satisfy this criterion even when using active gears but for each increase in vessel size class there is a necessity for a greater input of fossil fuel energy for each unit of energy harvested.

TABLE 8: Specific Cost by Vessel/Gear Combinations (Fuel/Landings)

Vessel	Gear Type	Fuel (cost $)	Landings[I] Value (000)	Specific Cost	Rank
	Fixed				
Inshore	Traps (all types)	33416	5616	0.01	1
35-65ft.	Gillnets	189916	1024	0.02	2
125bhp	Longlines/Gillnets	64249	3002	0.02	2
	Handlines	1378	142	0.01	1
	Encircling				
	Scot. Seine	36517	607	0.06	6
	Pair Seine	3100	71	0.04	4
	Towed				
	Shrimp Trawl	100421	1976	0.05	5
	Side Trawl	71484	1876	0.04	4
	Stern Trawl	12230	454	0.03	3
	Scallop Dragger	689	27	0.03	3
Nearshore	Fixed				
65-100 ft.	Gillnets	9991	305	0.03	3
405 bhp main					
134 bhp aux.	Encircling				
	Scot. Seine	5856	44	0.13	9
	Towed				
	Shrimp Trawl	1550	15	0.11	8
	Side Trawl	11710	105	0.11	8
Offshore	Fixed				
100 ft.	Gillnets	22909	244	0.09	7
1230 bhp main	Longlines/gillnets	12747	115	0.11	8
406 bhp aux.					
	Towed				
	Shrimp Trawl	142623	950	0.15	9
	Side Trawl	2637148	4269	0.62	12
	Stern Trawl	8472445	24663	0.34	11
	Midwater Trawl	255277	1081	0.24	10

[I]This is total landed value of all species landed as recorded by Department of Fisheries and Oceans

TABLE 9: Energy Ratios by Vessel/Gear Combinations (Fuel/Landings)

Vessel	Gear Type	Fuel Energy G.J.	Catch Energy G.J.	Energy Ratio	Rank
Inshore 35-65 feet	Fixed Gear				
	Traps (all types)	8350	64847	0.1	1
	Gillnets	38782	192070	0.2	2
	Longlines/ Gillnets	14938	39125	0.4	3
	Handlines	341	2013	0.2	2
	Encircling Gear				
	Scottish Seine	9144	8384	1.1	7
	Pair Seine	804	1145	0.7	5
	Towed Gear				
	Shrimp Trawl	24624	14931	1.6	10
	Side Otter Trawl	17500	26590	0.7	5
	Stern Otter Trawl	2986	6672	0.5	4
	Scallop Dragger	188	157	1.2	8
Nearshore 65-100 feet	Fixed Gear				
	Gillnets	9983	7749	1.3	9
	Encircling Gear				
	Scottish Seine	1430	789	1.8	11
	Towed Gear				
	Shrimp Trawl	378	125	3.0	16
	Side Otter Trawl	2890	1641	1.8	11
Offshore 100 feet	Fixed Gear				
	Gillnets	5728	6109	0.9	6
	Longlines/ Gillnets	2763	1739	1.6	10
	Towed Gear				
	Shrimp Trawl	34225	6452	5.3	14
	Side Otter Trawl	632610	108240	5.9	15
	Stern Otter Trawl	2032700	525000	3.9	13
	Mid-water Trawl	61211	32357	1.9	12

In discussions so far no consideration has been given to the fact that whereas the nearshore vessels operate with a small crew and for approximately one day per trip, the offshore fleet uses a larger crew and stays at sea longer. In Table 10 it can be seen that the catch per man trip is considerably higher for the larger vessels however the daily catch per man in all fisheries approximate 1 tonne/day. No statistical correlation could be established between the specific usage and the catch per man day fished. It must be recoqnized that the recording of days fished by fixed gears is not useful in this respect and the average values for crew sizes and days per trip may not be highly accurate. Despite this limitation the small vessels using fixed gear whose trip length would be one day or less catch 0.5 - 0.8 tonnes/man trip (which an average would equal a man day) and the catch per man for offshore stern trawlers, for which effort data is more reliable, is 0.9 tonnes per day. This means that we can perhaps eliminate the manpower cost from consideration since the labour input into catching a tonne of fish is rather similar throughout the fishery if we assume taht inshore and offshore earnings are similar. The same consideration would be valid in the energy quotient where the imput of human energy per tonne of fish is similar at both extremes of the harvesting sector. The relative consistency of the catch/manday index suggests that there is little way of replacinq manual labour usinq fossil fuel based energy or vice versa.

Table 10: Catch Per Man Trip and Specific Usage

Vessel Length Class	Gear Type	Trips/Year	Annual Landings (mt)	Specific Usage	All Species Catch/Mantrip (tonnes)	Average Days Fished Per Trip	Average All Species Catch Per Man Per Fishing Day[1]
35-65ft Average Crew:3.4 men	Traps	5865	15521	0.01	0.78	-	0.78
	Gillnets	19618	38671	0.03	0.58	-	0.58
	Longlines/Gillnets	5220	9473	0.04	0.53	-	0.53
	Handlines	726	491	0.02	0.20	-	0.20
	Ringnets	2007	22477	-	3.30	-	-
	Purse Seines	1	9	-	2.70	-	-
	Beach Seines	568	4514	-	2.34	-	-
	Danish Seines	243	1886	0.10	2.28	3.2	0.71
	Scottish Seines	62	208	0.09	0.99	1.3	0.76
	Pair Seines	60	282	0.06	1.38	1.4	0.99
	Shrimp Trawling	2366	3509	0.17	0.44	1.02	0.43
	Side Otter Trawling	1250	6454	0.06	1.52	1.33	1.14
	Stern Otter Trawling	130	1646	0.04	3.72	2.65	1.40
	Scallop Dragger	14	37	0.12	0.78	1.0	0.78
53-100ft. Average Crew:5.9men	Gillnets	80	1323	0.04	4.86	2.9	1.68
	Purse Seines	117	7597	-	-	-	-
	Scottish Seines	6	197	0.17	5.55	5.0	1.11
	Shrimp Trawling	2	27	0.33	2.26	4.5	0.50
	Side Otter Trawling	13	407	0.17	5.30	4.5	1.18
>100ft. Average Crew:13.4men	Gillnets	67	1050	0.13	1.16	2.6	0.45
	Longlines/Gillnets	10	423	0.18	3.15	8.5	0.37
	Purse Seines	134	13900	-	7.74	-	-
	Shrimp Trawling	12	1532	0.54	9.56	14.9	0.64
	Side Otter Trawling	469	26601	0.58	4.23	7.9	0.54
	Stern Otter Trawling	1242	128293	0.38	7.70	9.1	0.85
	Midwater Trawling	63	8092	0.18	9.58	6.3	1.52

1. Catch (mt)/Mantrip = $\frac{\text{Annual Catch (mt)}}{\text{Average Crew} \times \text{\# Trips per Year}}$

Catch per manday fished = Catch per mantrip x $\frac{\text{days fished}}{\text{number of trips}}$

CONCLUSIONS

This study took up an approach outlined by Endal for examination of fuel use by the Norwegian fishery. The approach requires an evaluation of the total amount of fuel used annually by each vessel-gear combination to land its catch. In this study data was used from the entire Newfoundand fleet and also from a survey of a small number of vessels. In each case there is evidence of a high variability of fuel efficiency in the Newfoundland fleet. This approach to the analysis has not allowed a close enough examination to be able to conclude exactly what are the optimum vessels-gear combinations.

In order to make this assessment, some basic assumptions were made pertaining to patterns of engine use. Any significant deviations which were made in these assumptions, relative to current practices in one or more fleet segments, could have some effect on the possible interpretation of results. In general it is noted that assumptions about engine use, average power and travelling time would have tended to minimize the difference in estimates of efficiency indices.

If the assumption of this study are tenable, and it seems that they could tend to minimize differences, it is possible to point at least to some gross differences in fuel efficiency which do exist in the Newfoundland fishery. There is a high variability which would indicate that the fishery does contain both highly efficient and grossly inefficient operations but in considering the fishery as a whole it is clear that fixed gear fisheries are more fuel efficient than fisheries using dynamic gears. The data examined in this study show a distinct trend that smaller vessels are more fuel efficent than the larger vessels but, with no examination of the efficiency indices of vessels less than 35 feet, it has not been possible to do more than suggest that they may be as efficient as those from 35 - 65 feet. Perhaps the value of this study has been to make an analysis from which detailed hypotheses can be set up which should then be tested with a more specific approach.

Further work to assess the fuel efficiency of various vessel-gear combinations could be designed to closely monitor fuel use and fishing activities for samples of vessels within particular vessel-gear combinations in order to make a recommendation of a technological nature. The general approach taken by this study could also be improved if a detailed analysis of power used by vessels in each fishery, including the patterns of engine use and sizes of engines used in each fishery, were more accurately known. Extension of the approach taken in this study might aid in definition of the optimum combinations of harvesting strategies for the Newfoundland fishery.

CALCULATIONS FROM SURVEY - August 22, 1980

LENGTH	BHP	DISTANCE TO GROUNDS (miles)	AREA FISHED	GEAR TYPE	SPECIFIC USAGE			SPECIFIC COST		
					ANNUAL CATCH (lbs)	ANNUAL FUEL CONSUMPTION (lbs)	SPECIFIC USAGE	LANDED VALUE $	FUEL COST $	SPECIFIC COST
	250	15	Conception Bay Trinity Bay	Cod Traps Gillnets Longlines	360,000	62,916	0.175	63,000	6,480 (5,530)	0.103 (0.09)
		2	Bonavista Bay	Squid Jigger	11,000	2,330	0.212	2,420	240 (205)	0.099 (0.08)
		9-11		Ring Nets Purse Seines	409,000	12,428	0.030	44,135	1,280 (1,092)	0.029 (0.02)
	365	70	Bonne Bay St. Anthony	Side Otter	500,000	90,270	0.181	87,500	8,000 (7,934)	0.091 (0.09)
				Shrimp Trawl	200,000	84,854	0.424	78,000	7,520 (7,548)	0.096 (0.10)
	269	30	N.E. Avalon	Crab Pots	1,000,000	151,818	0.152	270,000	12,000 (13,344)	0.044 (0.05)
	365	35	The Gulf Cape Breton Shore	Longlines Danish Seines Scottish Seines	800,000	91,646	0.115	136,000	9,000 (8,055)	0.066 (0.06)
	265		The Funks N.D. Bay	Cod Traps Gillnets Handlines	250,000	60,466	0.242	36,250	6,300 (5,314)	0.174 (0.15)
				Ring Nets Purse Seines	700,000	22,459	0.032	75,000	2,340 (1,974)	0.031 (0.03)
	360	14	Cape Breton Shore The Gulf Strait of Belle Isle	Longlines	1,200,000	100,602	0.084	180,000	10,000 (8,842)	0.056 (0.05)
	360	50	Strait of Belle Isle	Side Otter Trawl	700,000	90,180	0.129	122,500	8,100 (7,926)	0.066 (0.06)
		70-100		Shrimp Trawl	340,000	70,140	0.206	132,600	6,300 (6,165)	0.048 (0.05)
	365	40	Notre Dame Bay	Crab Pots	740,000	92,353	0.125	199,800	9,180 (8,117)	0.046 (0.04)
		10-14	Cape Race	Ring Nets Purse Seine	1,480,000	18,611	0.013	79,600	1,850 (1,636)	0.023 (0.02)
	340	42	N.D. Bay Port de Grave Cape Race	Crab Pots	1,100,000	129,226	0.118	297,000	13,000 (11,358)	0.044 (0.04)
	365	8-12	North East Coast	Purse Seine Pair Seine Midwater Trawl	600,000	17,971	0.030	51,875	1,485 (1,579)	0.029 (0.03)
		40	Cape Race to St. Mary's	Crab Pots	640,000	106,735	0.167	172,800	8,820 (9,381)	0.051 (0.05)

NGTH	BHP	DISTANCE TO GROUNDS (miles)	AREA FISHED	GEAR TYPE	SPECIFIC USAGE: ANNUAL CATCH (lbs)	SPECIFIC USAGE: ANNUAL FUEL CONSUMPTION (lbs)	SPECIFIC USAGE: SPECIFIC USAGE	SPECIFIC COST: LANDED VALUE $	SPECIFIC COST: FUEL COST $	SPECIFIC COST: SPECIFIC COST
	222	13	White Bay Notre Dame Bay Trinity Bay	Cod Traps Gillnets Handlines Stern Trawl	555,000	25,150	0.045	71,850	2,500 (2,184)	0.035 (0.03)
		9-22	Bonavista Bay	Squid Jigger	30,000	1,489	0.050	3,000	148 (129)	0.049 (0.04)
	260	12	North East Coast Trinity Bay	Cod Traps Gillnets	250,000	17,396	0.070	35,000	1,750 (1,511)	0.050 (0.04)
		4	to Cape	Ring Nets Purse Seine	1,000,000	19,682	0.020	105,000	1,980 (1,710)	0.019 (0.02)
	155	20	Notre Dame Bay	Gillnets Longliners	560,000	38,901	0.070	67,200	3,960 (3,419)	0.059 (0.05)
		3	Trinity Bay	Squid Jigger	70,000	4,421	0.063	7,700	450 (389)	0.058 (0.05)
		35	White Bay	Ring Nets Purse Seine	280,000	2,456	0.009	30,800	250 (216)	0.008 (0.01)
	250	20	St. Mary's Bay Trinity Bay	Cod Traps Gillnets Handlines Longlines	350,000	40,822	0.117	49,000	4,400 (3,588)	0.090 (0.07)
		11-30		Purse Seine	700,000	14,473	0.021	73,000	1,560 (1,272)	0.021 (0.02)
				Squid Jigger	50,000	2,598	0.052	5,500	280 (228)	0.051 (0.04)
	230	32	Funks Bonavista Bay Labrador	Gillnets	700,000	73,317	0.105	98,000	7,200 (6,444)	0.071 (0.07)
	250	30	N.D. Bay Bonavista Bay The Funks	Gillnets	311,000	28,904	0.093	41,985	3,150 (2,785)	0.075 (0.07)
		2		Ring Nets Purse Seine	850,000	9,176	0.011	91,500	1,000 (884)	0.011 (0.01)
	170	25	St. Mary's Trinity Bay	Cod Traps Gillnets Longlines	500,000	53,219	0.106	70,000	5,290 (4,914)	0.076 (0.07)
		2	Bonavista Bay	Squid Jigger	7,000	1,509	0.216	630	150 (139)	0.238 (0.22)
		5		Ring Nets Purse Seine	300,000	3,320	0.011	33,000	330 (307)	0.010 (0.01)
	210	20	Cape St.	Gillnets Handlines Longlines	500,000	84,557	0.169	72,500	8,000 (7,432)	0.110 (0.10)
		6	Cape Ball	Purse Seines	500,000	16,911	0.034	15,000	1,600 (1,486)	0.107 (0.10)
	225	12-14	White Bay	Gillnets	200,000	8,231	0.041	22,000	690 (723)	0.031 (0.03)
		2-3	Bonavista Bay	Squid Jigger	40,000	1,431	0.036	4,800	120 (126)	0.025 (0.03)
		40-110		Ring Nets Purse Seine	560,000	37,754	0.067	50,900	3,165 (3,318)	0.062 (0.07)
	250	12	Bonavista to	Gillnets	210,000	57,691	0.275	32,550	5,320 (5,070)	0.163 (0.16)
		4	Trinity Bay	Squid Jigger	40,000	3,036	0.076	4,800	280 (267)	0.058 (0.06)
		5		Purse Seine	250,000	17,893	0.072	27,500	1,650	0.060

SSEL >35 - ≤45

CALCULATIONS FROM SURVEY - August 22, 1980

LENGTH T)	BHP	DISTANCE TO GROUNDS (miles)	AREA FISHED	GEAR TYPE	SPECIFIC USAGE			SPECIFIC COST		
					ANNUAL CATCH (lbs)	ANNUAL FUEL CONSUMPTION (lbs)	SPECIFIC USAGE	LANDED VALUE $	FUEL COST $	SPECIFIC COST
38	100	10	Port aux Port Bay	Cod Traps Gillnets	15,000	2,996	0.200	2,700	348 (263)	0.129 (0.10)
				Scallop Dragger	1,000	2,582	2.582	2,800	300 (277)	0.107 (0.08)
38	75	8	Leading Tickle	Gillnets Longlines	200,000	14,195	0.071	24,000	1,326 (1,248)	0.055 (0.05)
		5		Beach Seine	150,000	4,978	0.033	12,200	465 (438)	0.038 (0.04)
38	115	10	Fortune Bay	Longlines	387,000	13,324	0.034	77,445	1,117 (1,171)	0.014 (0.02)
39	65	10	Green Bay	Gillnets Longlines Handlines	35,000	7,219	0.206	4,400	830 (635)	0.189 (0.14)
				Squid Jiggers	2,000	696	0.348	230	80 (61)	0.348 (0.27)
		15		Beach Seines	156,000	8,968	0.058	14,300	1,031 (788)	0.072 (0.06)
40	150	15	Bonavista Bay Northeast Coast	Gillnets Handlines	280,000	4,234	0.015	35,000	360 (372)	0.010 (0.01)
				Squid Jiggers	60,000	3,058	0.051	6,500	260 (269)	0.039 (0.04)
				Ring Nets Purse Seine Beach Seine	110,000	11,114	0.101	10,000	945 (977)	0.095 (0.10)
41	125	12	Port aux Choix to Cooks Hr.	Gillnets	230,000	26,935	0.117	28,000	3,000 (2,367)	0.107 (0.08)
45	117	½ mile	Bonavista Bay	Squid Traps	500,000	6,863	0.014	55,000	600 (603)	0.011 (0.01)
45	80	12		Gillnets Handlines	850,000	28,781	0.034	150,400	3,240 (2,530)	0.021 (0.02)
45	165	25 miles	Bonavista Bay & Trinity Bay	Crab Pots	400,000	73,504	0.184	108,000	6,250 (5,097)	0.058 (0.05)
45	156	27	Funk Area	Gillnets Handlines	450,000	31,313	0.070	60,000	3,375 (2,984)	0.056 (0.05)

L LENGTH T)	BHP	DISTANCE TO GROUNDS (miles)	AREA FISHED	GEAR TYPE	SPECIFIC USAGE			SPECIFIC COST		
					ANNUAL CATCH (lbs)	ANNUAL FUEL CONSUMPTION (lbs)	SPECIFIC USAGE	LANDED VALUE $	FUEL COST $	SPECIFIC COST
	8	10		Cod Traps Gillnets Longlines	50,000	3,055	0.061	7,250	392 (269)	0.054 (0.04)
	33	10	Placentia Bay	Gillnets Handlines Longlines	160,000	17,688	0.111	27,200	1,504 (1,555)	0.055 (0.06)
		5 miles		Squid Jigger	50,000	1,646	0.033	5,600	140 (145)	0.025 (0.03)
		3-12		Beach Seines	46,000	3,352	0.073	2,500	285 (294)	0.114 (0.12)
	22	4	Conception Bay	Cod Traps Gillnets	10,000	1,713	0.171	1,800	160 (150)	0.089 (0.08)
		Inshore		Squid Jigger	10,000	3,212	0.321	1,100	300 (282)	0.273 (0.26)
	4			Bar Seines Beach Seines	150,000	9,742	0.064	5,775	910 (856)	0.158 (0.15)
	22	3-4	Notre Dame Bay	Gillnets	90,000	3,939	0.044	9,600	368 (346)	0.038 (0.04)
		1/2		Herring Seines	35,000	2,141	0.061	2,300	200 (188)	0.087 (0.08)
1/2	33	8	St. Mary's/ Southside Placentia	Gillnets Handlines Cod Traps	100,000	7,900	0.08	20,000	600 (579)	0.030 (0.03)
	85	20	Cape John to Partridge Point	Cod Traps Gillnets Handlines LongLiners	200,000	7,644	0.038	18,000	650 (672)	0.036 (0.04)
		2		Squid Jigger	8,000	1,646	0.206	900	140 (145)	0.156 (0.16)
		3		Bar Seines Beach Seines Midwater Trawls	75,000	2,117	0.028	8,000	180 (186)	0.023 (0.02)
	85	12	Placentia Bay	Cod Traps Gillnets Handlines	150,000	10,191	0.068	21,000	952 (984)	0.045 (0.05)
		12		Squid Jigger	12,000	1,285	0.107	1,400	120 (124)	0.086 (0.09)
		14		Beach Seines	42,000	2,302	0.055	8,100	215 (222)	0.027 (0.03)
	90	2	Notre Dame Bay	Gillnets Handlines Longlines	120,000	9,165	0.076	13,000	900 (806)	0.069 (0.06)
		8		Squid Jigger	40,000	2,851	0.071	3,500	280 (251)	0.080 (0.07)
	85	18	Placentia Bay	Gillnets Handlines Longlines	120,000	17,994	0.150	21,600	1,530 (1582)	0.071 (0.07)
		12		Squid Jigger	40,000	2,823	0.071	4,500	240 (248)	0.053 (0.06)
		8		Beach Seine	22,500	7,830	0.348	5,400	665 (687)	0.123 (0.13)
	85	16	Bay of Islands	Cod Traps Gillnets Handlines	150,000	10,835	0.072	19,500	1,064 (952)	0.055 (0.05)
		4		Squid Jigger	50,000	2,749	0.055	5,600	270 (242)	0.048 (0.04)
		3		Capelin Seine	30,000	1,629	0.054	2,020	140	

APPENDIX I

Data from Survey of Landings and Fuel Consumption of a Sample of Newfoundland Fishing Vessels

The data presented in these appendices was obtained by surveying a number of fishermen. Since the data was partially extracted from their confidential accounting information, NORDCO was unable to verify its accuracy. Unfortunately data could not be provided which would allow evaluation of the performance of specific gears utilized by individual boats and any analysis suffers from our inability to separate, for example, the performance of an otter trawl and the same vessel using cod traps. The data are presented here in the hope that they explain some of the complexity associated with any analysis of the fuel efficiency in the Newfoundland fishery.

If this data shows anything it points to the variability of the vessels employed in any fishery and the opportunistic habit of Newfoundland fishermen as witnessed by 55 foot vessels with 250 bhp engines fishing for squid. The enormous variability in boat types engaged in particular fisheries is also evidenced by a 50 foot, 222 bhp stern trawler to a 65 foot, 360 bhp side trawler and a 26 foot 8 bhp boat to a 65 foot 360 bhp vessel, both using longlines.

Under specific cost we have estimated the value of fuel used in terms of a standard averaqe Newfoundland fuel price of 73.39¢/qallon. These additional values and estimates are presented in parantheses in the table and represent a standardization of specific cost in terms of 1979 costs and values. Despite the stated range of fuel prices from 71 to 107¢ per gallon this correction does not reduce significantly the variability exhibited by the sample.

APPENDIX II

Energy Consumption in Various Norwegian Fisheries

by

A. Endal, ICES Fishing Technology Committee, C.M. 1979/B:3

Summary

This paper is a review of recent research into the use of energy in Norwegian fishing operations.

1. The energy consumption for producing food from the ocean seems to be very high, considerably higher than for comparable products from agriculture.
2. Depending the fishing method there seems to be great differences in the amount of fuel used per ton of fish.
3. There is considerable scope for improvements in the fuel consumption, by adapting low-energy fishing methods and gear, and the further use of waste heat in exhaust gas and cooling water.
4. Future increases in oil prices will stimulate the use of passive methods, while trawling will be of a disadvantage.

Until recently the use of energy has got little attention in our fisheries, apart from traditional efforts to reduce resistance and increase populsive efficiency.

The oil has been, and continues to be, inexpensive. The efforts have been concentrated on improving catch-rates, yield per unit of effort, on reducing labour requirements, etc.

It is evident that the energy consumption per ton fish has increased drastically over the years, with dwindling fish stocks, increased engine power and the need for fishing further offshore.

It is a foregone conclusion that oil prices will increase more rapidly in the future than we have been used to in the past, and even if predictions vary wildly, the growing concern is reflected in the number of studies that have been carried out to determine fuel consumption in different fisheries in Norway.

In the following I shall give a brief summary of results from some of these studies.

The total use of energy in our fisheries includes items that are rather difficult to estimate, such as the energy represented by machinery, vessels and gear, which should be written off over a number of years. Energy used by the fishermen's own labour is also difficult to establish. However, the most important item in this total picutre, is the fuel, and overwhelmingly so. One way of measuring the energy efficiency of various fishing operations is to relate total energy usued to the total energy yield from the catch.

Dividing the energy yield by the total used energy provides us with a non-dimensional figure which we may call the "energy quotient" for that particular fishery.

The following table may give us some food for thought.

This table indicates that trawling energywise is a very poor performer, compared to purse-seining.

Vessel and Fishery	Oil Energy G.J	Total Energy G.J	Catch Energy G.J	Energy Quotient
40-60 ft vessels nets and longlines Finnmark	1863	2621	1206	0.46
Over 60 ft vessels nets and longlines Continental Shelf North Norway	4627	6084	1788	0.29
Wet fish sterntrawlers over 200 tons	40.802	46.731	5121	0.11
"Sardine" fisheries purse seiners	1.135	1.738	1.290	0.75
Purse seining all vessels over 80 ft	15.688	21.622	55.846	2.58
Shrimp trawling North Norway	992	1293	71.2	0.055

However, the picture may be somewhat distorted due to the high energy content in the fact species caught by purse seiners.

The Norwegian fishing fleet uses 450.000 tons of fuel in a year, at a toal cost of N.Kr. 380 million (1977). The fuel costs amount to approximately 12% of the total landed value. The average fuel costs is about N.Kr. 400. per installed HP in our fleet (1977).

Most fishermen show a large interest in getting the highest possible speed from their vessel. During the last couple of decades there has been a dramatic increase in installed horsepower in our fihsing fleets, most small and medium size vessels are heavily over-powered. A rough estimate is that if only half the horsepower were used, the average speed of the Norwegian fleet would be reduced by 10%. In spite of this quest for speed, our institute has been unable to show any economic justification for increase in speed, except maybe for purse seiners.

The following table shows catch per man year and oil consumption per kg fish for different methods of fishing. The values shown are not pretented to be accurate, but are intended to illustrate the problems imposed by rising fuel prices.

In relation to energy the factory vessels show a better performance then the wet fish trawlers and, in addition, the 100 tons of fish each man catches in a year is completely processed onboard the vessel.

Method of Fishing	Catch per Man Year	Kg Fuel per kg of Fish
Coastal fishing net and longline North Norway	30-40 tons	0.075
Longlining Continental Shelf	40-50 tons	0.140
Factory vessels	90-110 tons	0.290
Wet fish trawling North Norway	90-110 tons	0.370

If we plot catch per man year against fuel consumption per kg fish landed for the different fisheries we get the following picture.

These figures indicate that there at present is a linear relationship between the fuel used and the landed tonnage per manyear in our fisheries for bottom species.

This may soon change. Recent experiments carried outu at our Gear Division in Bergen, indicate that there is a great potential for improving the catch-rates for longlining, and an increase in handling speed will also add to the annual output of each fisherman in this fishery.

With the relatively efficient use of fuel at present, and with the scope for improvements in output per man and increased fuel efficiency in the future, longlining is likely to be an important method of fishing in the years to come.

With increasing fuel-prices, trawling may be at a disadvantage. A doubling, tripling or maybe a tenfold increase in fuel cost will bring about drastic changes in our fisheries, and will most certainly greatly stimulate gear research in the future.

Sixty to seventy percent of the fuel energy is not used and disappears by exhaust and cooling water system.

Methods for using this waste heat are being developed, and will become important in the coming years. This heat could be used for production of electric power, which today cost about N.Kr. 0,50 pere KWh, for heating or cooling purposes, or for processing.

The rising cost of energy will most likely become the most important challenge to fishery technology research in the future.

Fuel Consumption 1977
(FTFI 1979)

Type of Vessel and Fishery	Fuel Tons	Catch Tons	Specific Consumption
Sterntrawlers over 200 GRT North Norway, wet fish	1003	1560	0.64
Nets and Scottish seine coastal 40-69 ft Finnmark	34.8	275	0.127
Nets, Scottish seine 40-69 ft coastal Troms	47.0	441	0.110
Longlining coastal, 40-69 ft Troms and Finmark	43.3	242	0.179
Longlining, over 60 ft Continental Shelf, S. Norway	178	590	0.30
Longling, over 70 ft Continental Shelf, N. Norway	142	804	0.18
Purse seining 600-800 ton capacity vessel	343	8400	0.064
Purse seining 800 tons and over vessels	1009	15000	0.067